Applied Physics Laboratory
College of Ocean and Fishery Sciences, University of Washington

1943–1993 — 50 Years of Excellence

1 June 1995

Office of Naval Research
S.O. Code 124
800 N. Quincy Street
Arlington, VA 22217-5000

To whom it may concern:

I submit the attached Final Report on "Low Frequency Reverberation Zone from the Ocean Surface Zone," in compliance with requirements specified for ONR grant #N00014-92-J-1338. The appropriate number of copies have been distributed to the Defense Technical Information Center, NRL and the University of Washington ONR Resident Representative.

Sincerely yours,

Frank S Henyey

Frank S. Henyey
Principal Investigator

1013 NE 40th Street Seattle, Washington 98105-6698 (206) 543-1300 FAX (206) 543-6785

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
SEATTLE REGIONAL OFFICE
1107 NE 45TH STREET, SUITE 350
SEATTLE WA 98105-4631

IN REPLY REFER TO:

4330
ONR 247
11 Jul 97

From: Director, Office of Naval Research, Seattle Regional Office, 1107 NE 45th St., Suite 350, Seattle, WA 98105
To: Defense Technical Center, Attn: P. Mawby, 8725 John J. Kingman Rd., Suite 0944, Ft. Belvoir, VA 22060-6218

Subj: RETURNED GRANTEE/CONTRACTOR TECHNICAL REPORTS

1. This confirms our conversations of 27 Feb 97 and 11 Jul 97. Enclosed are a number of technical reports which were returned to our agency for lack of clear distribution availability statement. This confirms that all reports are unclassified and are "APPROVED FOR PUBLIC RELEASE" with no restrictions.

2. Please contact me if you require additional information. My e-mail is *silverr@onr.navy.mil* and my phone is (206) 625-3196.

ROBERT J. SILVERMAN

REPORT DOCUMENTATION PAGE

Form Approved
OPM No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	Report Date	Technical

4. TITLE AND SUBTITLE
LOW FREQUENCY REVERBERATION ZONE FROM THE OCEAN SURFACE ZONE

5. FUNDING NUMBERS
ONR Grant
#N00014-92-J-1338

6. AUTHOR(S)
Frank S. Henyey

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Applied Physics Laboratory
University of Washington
1013 NE 40th Street
Seattle, WA 98105-6698

8. PERFORMING ORGANIZATION REPORT NUMBER
none

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Office of Naval Research
Code 124
800 N. Quincy Street
Arlington, VA 22217-5000

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
None

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution Statement

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

This project involved participation in three experiments on low-frequency acoustic reverberation form the ocean surface zone: 1) CST-7 Phase 2, 2) CABEX I and 3) CABEX II. Details of these experiments are contained in the cruise reports and in the final report from CST-7. In addition, there are numerous reports and transparency collections from the CST surface scattering working group.

14. SUBJECT TERMS
Subject Terms

15. NUMBER OF PAGES
Pages

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

Final Report on Grant #N00014-92-J-1338

LOW FREQUENCY REVERBERATION FROM THE OCEAN SURFACE ZONE

Frank Henyey, Principal Investigator
Applied Physics Laboratory, University of Washington

Prepared 6/1/95

This project involved participation in three experiments on low-frequency acoustic reverberation from the ocean surface zone: 1) CST-7 Phase 2, 2) CABEX I and 3) CABEX II. Details of these experiments are contained in the cruise reports and in the final report from CST-7. In addition, there are numerous reports and transparency collections from the CST surface scattering working group.

During the early stages of this project, a document suggesting hypothesis testing was prepared by Frank Henyey. Mel Briscoe, an ONR program manager at the time, suggested that the document be used as a primary planning document for CST-7. After some modification, the document was endorsed by the ARSRP surface "executive committee" (Farmer, Ewart, Henyey, Melville, Prosperetti), and was used in planning CST-7, as well as in influencing the CABEX and ASREX experiments. The distinction between dense bubble clouds associated with breaking waves and the tenuous clouds associated with Langmuir circulation was delineated in that report, and appropriate tests for the dominance of each hypothesis were suggested. In particular, frequency shifts due to the short lifetime of dense clouds were suggested as a crucial test of the dense cloud hypothesis.

Such frequency shifts must be compared with those expected in the tenuous cloud hypothesis. A component of CST-7, the FOSS (forward ocean surface scattering) experiment was designed by Henyey and Farmer to address the issues of wave effects on the insonifying field. This experiment was designed to test hypotheses following from previous modeling by Ewart and Thorsos. There were two types of sources used. The small explosive sources gave results that are entirely consistent with modeling by Thorsos. The 30 sec CW sources gave results that were in many ways qualitatively similar to Thorsos's results. Since the time of the comparison between modeling and experiment, we have become aware of an uncertainty in the value of the grazing angle for that part of the FOSS experiment. It appears that with our current best guess as to the grazing angle, the data and modeling will agree considerably better, but the revised modeling has not yet been done. Although intensity variations are apparent in the time series, they are essentially negligible in the

frequency shift spectrum. The frequency shifts are consistent with dominance by orbital Doppler spread.

Based on the success of the FOSS results, Thorsos applied his orbital Doppler modeling to Roger Gauss's reverberation frequency shift data, as suggested in the hypothesis-testing report. Thorsos and Gauss found results consistent with the tenuous bubble cloud hypothesis, and they were able to rule out the dense bubble cloud hypothesis, based on dense cloud data taken in CST-7. Other hypothesis testing work (by J. Hanson) has also given strong positive evidence for the tenuous cloud hypothesis.

The CST-7 program was a collaboration of many investigators and was very successful in many ways. The participation of this grant in that program was designed to provide vertical integration (called "6.15" work at the start of these efforts) in the CST program. This vertical integration was important in the success of CST-7, and can be used as a model for how vertical integration should function. Commitment to vertical integration by the program managers, and by both the 6.3 and 6.1 researchers made it work.

The CABEX experiment was designed to exploit new imaging algorithms. Resolution is achieved by spatial diversity, but the need for a filled array with CW signals is replaced by use of bandwidth. In particular, an imager that is a generalized matched field detector was designed. The method for dealing with a high-dimensional optimization problem is to put the image together one object at a time. With enough resolution and enough intermittency (spacing between the objects), this method will work.

Unfortunately, the bandwidth of the CABEX hardware was not as large as we had hoped (it was a factor of 20 smaller), and the intermittency was about what we anticipated. The bandwidth was borderline for the application of this method. It did as well as another advanced imaging algorithm, but with more bandwidth it should have greatly outperformed the other methods we used.

Our algorithm is much more general than the CABEX application, and we look forward to verifying it in more favorable conditions. In particular, at frequencies of many tens of kilohertz, the needed bandwidth is much more readily available.

The CABEX experiment involved both high-frequency imaging of tenuous bubble clouds and low-frequency reverberation imaging. The idea was to correlate the two types of images. Although there are many images from each instrument separately, there are relatively few simultaneous images. We do not have any convincing identification of common features in the two types of images.

The CABEX array and imaging algorithms were used to image ice reverberation in the IBEX experiment. Reverberation features in that experiment do coincide with features in optical images of the upper surface of the ice, but the lack of more bandwidth is also apparent in that experiment. The third year of funding on this grant was withdrawn. The first two years were dedicated to planning and carrying out the experiments, and to developing analysis algorithms. The actual analysis and publication of the results was to have taken place in the third year. Some of the work is being completed, where appropriate, under other funding.